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**Chemistry**  
**Standard level**  
**Paper 1**

Wednesday 10 November 2021 (afternoon)

45 minutes

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**Instructions to candidates**

- Do not open this examination paper until instructed to do so.
- Answer all the questions.
- For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
- The periodic table is provided for reference on page 2 of this examination paper.
- The maximum mark for this examination paper is **[30 marks]**.

# The Periodic Table

|   | 1                         | 2                         | 3                           | 4                         | 5                         | 6                         | 7                         | 8                         | 9                         | 10                        | 11                        | 12                        | 13                         | 14                         | 15                         | 16                         | 17                         | 18                         |  |
|---|---------------------------|---------------------------|-----------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|--|
| 1 | 1<br><b>H</b><br>1.01     | Atomic number             |                             |                           |                           |                           |                           |                           |                           |                           |                           |                           |                            |                            |                            |                            |                            |                            |  |
| 2 | 3<br><b>Li</b><br>6.94    | 4<br><b>Be</b><br>9.01    | Element                     |                           |                           |                           |                           |                           |                           |                           |                           |                           |                            |                            |                            |                            |                            |                            |  |
| 3 | 11<br><b>Na</b><br>22.99  | 12<br><b>Mg</b><br>24.31  | Relative atomic mass        |                           |                           |                           |                           |                           |                           |                           |                           |                           |                            |                            |                            |                            |                            |                            |  |
| 4 | 19<br><b>K</b><br>39.10   | 20<br><b>Ca</b><br>40.08  | 21<br><b>Sc</b><br>44.96    | 22<br><b>Ti</b><br>47.87  | 23<br><b>V</b><br>50.94   | 24<br><b>Cr</b><br>52.00  | 25<br><b>Mn</b><br>54.94  | 26<br><b>Fe</b><br>55.85  | 27<br><b>Co</b><br>58.93  | 28<br><b>Ni</b><br>58.69  | 29<br><b>Cu</b><br>63.55  | 30<br><b>Zn</b><br>65.38  | 31<br><b>Ga</b><br>69.72   | 32<br><b>Ge</b><br>72.63   | 33<br><b>As</b><br>74.92   | 34<br><b>Se</b><br>78.96   | 35<br><b>Br</b><br>79.90   | 36<br><b>Kr</b><br>83.90   |  |
| 5 | 37<br><b>Rb</b><br>85.47  | 38<br><b>Sr</b><br>87.62  | 39<br><b>Y</b><br>88.91     | 40<br><b>Zr</b><br>91.22  | 41<br><b>Nb</b><br>92.91  | 42<br><b>Mo</b><br>95.96  | 43<br><b>Tc</b><br>(98)   | 44<br><b>Ru</b><br>101.07 | 45<br><b>Rh</b><br>102.91 | 46<br><b>Pd</b><br>106.42 | 47<br><b>Ag</b><br>107.87 | 48<br><b>Cd</b><br>112.41 | 49<br><b>In</b><br>114.82  | 50<br><b>Sn</b><br>118.71  | 51<br><b>Sb</b><br>121.76  | 52<br><b>Te</b><br>127.60  | 53<br><b>I</b><br>126.90   | 54<br><b>Xe</b><br>131.29  |  |
| 6 | 55<br><b>Cs</b><br>132.91 | 56<br><b>Ba</b><br>137.33 | 57 †<br><b>La</b><br>138.91 | 72<br><b>Hf</b><br>178.49 | 73<br><b>Ta</b><br>180.95 | 74<br><b>W</b><br>183.84  | 75<br><b>Re</b><br>186.21 | 76<br><b>Os</b><br>190.23 | 77<br><b>Ir</b><br>192.22 | 78<br><b>Pt</b><br>195.08 | 79<br><b>Au</b><br>196.97 | 80<br><b>Hg</b><br>200.59 | 81<br><b>Tl</b><br>204.38  | 82<br><b>Pb</b><br>207.2   | 83<br><b>Bi</b><br>208.98  | 84<br><b>Po</b><br>(209)   | 85<br><b>At</b><br>(210)   | 86<br><b>Rn</b><br>(222)   |  |
| 7 | 87<br><b>Fr</b><br>(223)  | 88<br><b>Ra</b><br>(226)  | 89 ‡<br><b>Ac</b><br>(227)  | 104<br><b>Rf</b><br>(267) | 105<br><b>Db</b><br>(268) | 106<br><b>Sg</b><br>(269) | 107<br><b>Bh</b><br>(270) | 108<br><b>Hs</b><br>(269) | 109<br><b>Mt</b><br>(278) | 110<br><b>Ds</b><br>(281) | 111<br><b>Rg</b><br>(281) | 112<br><b>Cn</b><br>(285) | 113<br><b>Unt</b><br>(286) | 114<br><b>Uug</b><br>(289) | 115<br><b>Uup</b><br>(288) | 116<br><b>Uuh</b><br>(293) | 117<br><b>Uus</b><br>(294) | 118<br><b>Uuo</b><br>(294) |  |
|   | †                         |                           |                             |                           |                           |                           |                           |                           |                           |                           |                           |                           |                            |                            |                            |                            |                            |                            |  |
|   | 58<br><b>Ce</b><br>140.12 | 59<br><b>Pr</b><br>140.91 | 60<br><b>Nd</b><br>144.24   | 61<br><b>Pm</b><br>(145)  | 62<br><b>Sm</b><br>150.36 | 63<br><b>Eu</b><br>151.96 | 64<br><b>Gd</b><br>157.25 | 65<br><b>Tb</b><br>158.93 | 66<br><b>Dy</b><br>162.50 | 67<br><b>Ho</b><br>164.93 | 68<br><b>Er</b><br>167.26 | 69<br><b>Tm</b><br>168.93 | 70<br><b>Yb</b><br>173.05  | 71<br><b>Lu</b><br>174.97  |                            |                            |                            |                            |  |
|   | ‡                         |                           |                             |                           |                           |                           |                           |                           |                           |                           |                           |                           |                            |                            |                            |                            |                            |                            |  |
|   | 90<br><b>Th</b><br>232.04 | 91<br><b>Pa</b><br>231.04 | 92<br><b>U</b><br>238.03    | 93<br><b>Np</b><br>(237)  | 94<br><b>Pu</b><br>(244)  | 95<br><b>Am</b><br>(243)  | 96<br><b>Cm</b><br>(247)  | 97<br><b>Bk</b><br>(247)  | 98<br><b>Cf</b><br>(251)  | 99<br><b>Es</b><br>(252)  | 100<br><b>Fm</b><br>(257) | 101<br><b>Md</b><br>(258) | 102<br><b>No</b><br>(259)  | 103<br><b>Lr</b><br>(262)  |                            |                            |                            |                            |  |

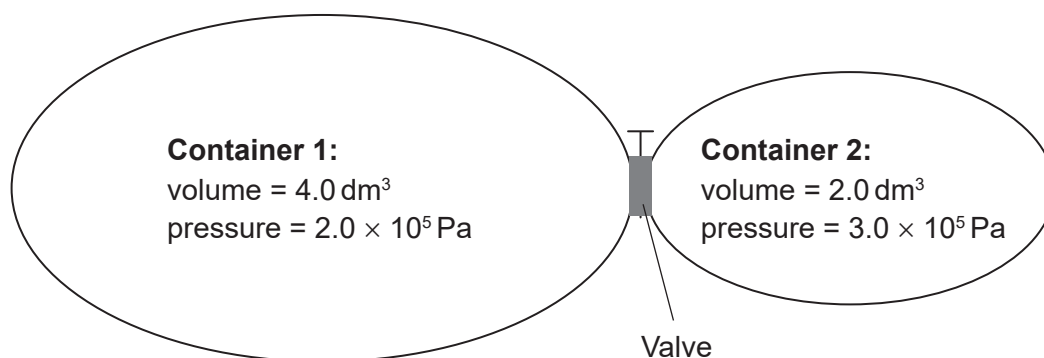
1. What is the number of hydrogen atoms in 2.00 moles of  $\text{Ca}(\text{HCO}_3)_2$ ?

Avogadro's constant,  $L$  or  $N_A$ :  $6.02 \times 10^{23} \text{ mol}^{-1}$

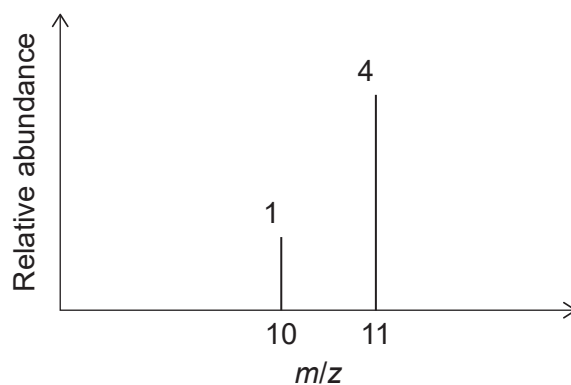
- A. 2.00
- B. 4.00
- C.  $1.20 \times 10^{24}$
- D.  $2.41 \times 10^{24}$
2. Which statement describes all homogeneous mixtures?
- A. Any sample has the same ratio of the components.
- B. The components are covalently bonded together.
- C. The components cannot be easily separated.
- D. The mixture needs a specific ratio of components to form.
3. Which combination is correct?

|    | Structural formula        | Empirical formula      | IHD |
|----|---------------------------|------------------------|-----|
| A. | $\text{C}_6\text{H}_{12}$ | $\text{C}_2\text{H}_4$ | 1   |
| B. | $\text{C}_6\text{H}_{14}$ | $\text{C}_3\text{H}_7$ | 0   |
| C. | $\text{C}_8\text{H}_8$    | CH                     | 3   |
| D. | $\text{C}_8\text{H}_{10}$ | $\text{C}_4\text{H}_6$ | 4   |

4. The two containers shown are connected by a valve. What is the total pressure after the valve is opened and the two gas samples are allowed to mix at constant temperature?



- A.  $1.5 \times 10^5 \text{ Pa}$   
B.  $2.3 \times 10^5 \text{ Pa}$   
C.  $2.5 \times 10^5 \text{ Pa}$   
D.  $5.0 \times 10^5 \text{ Pa}$
5. Consider the mass spectrum of an element:



What is the relative atomic mass of this element?

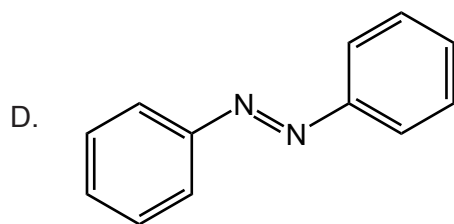
- A. 10.2  
B. 10.5  
C. 10.8  
D. 10.9

6. How many p-orbitals are occupied in a phosphorus atom?
- A. 2  
B. 3  
C. 5  
D. 6
7. Which element has the highest metallic character in Group 14?
- A. C  
B. Si  
C. Ge  
D. Sn
8. Which combination describes the acid–base nature of aluminium and phosphorus oxides?

|    | Aluminium        | Phosphorus       |
|----|------------------|------------------|
| A. | Amphoteric oxide | Acidic oxide     |
| B. | Basic oxide      | Amphoteric oxide |
| C. | Acidic oxide     | Amphoteric oxide |
| D. | Amphoteric oxide | Basic oxide      |

9. Which molecule has the **weakest** nitrogen to nitrogen bond?

- A.  $N_2$   
B.  $N_2H_2$   
C.  $N_2H_4$



10. Which combination would create the strongest ionic bond?

|    | Ionic radius | Charges on ions |
|----|--------------|-----------------|
| A. | large        | high            |
| B. | large        | low             |
| C. | small        | high            |
| D. | small        | low             |

11. Which compound contains both ionic and covalent bonds?

- A.  $\text{CH}_3\text{COONa}$
- B.  $\text{CH}_3\text{COOH}$
- C.  $\text{K}_2\text{O}$
- D.  $\text{CaCl}_2$

12. The following compounds have similar relative molecular masses. What is the order of increasing boiling point?

- A.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH} < \text{CH}_3\text{CH}_2\text{CHO} < \text{CH}_3\text{COOH}$
- B.  $\text{CH}_3\text{CH}_2\text{CHO} < \text{CH}_3\text{CH}_2\text{CH}_2\text{OH} < \text{CH}_3\text{COOH}$
- C.  $\text{CH}_3\text{CH}_2\text{CHO} < \text{CH}_3\text{COOH} < \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D.  $\text{CH}_3\text{COOH} < \text{CH}_3\text{CH}_2\text{CHO} < \text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$

13. Which alcohol is **least** soluble in water?

- A.  $\text{CH}_3\text{OH}$
- B.  $\text{CH}_3\text{CH}_2\text{OH}$
- C.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- D.  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$

14. Which combustion reaction releases the **least** energy per mole of  $C_3H_8$ ?

Approximate bond enthalpy /  $\text{kJ mol}^{-1}$

O=O      500

C=O      800

C≡O      1000

- A.  $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(g)$
- B.  $C_3H_8(g) + \frac{9}{2}O_2(g) \rightarrow 2CO_2(g) + CO(g) + 4H_2O(g)$
- C.  $C_3H_8(g) + 4O_2(g) \rightarrow CO_2(g) + 2CO(g) + 4H_2O(g)$
- D.  $C_3H_8(g) + \frac{7}{2}O_2(g) \rightarrow 3CO(g) + 4H_2O(g)$

15. Which equation represents the standard enthalpy of formation of lithium oxide?

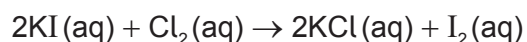
- A.  $4Li(s) + O_2(g) \rightarrow 2Li_2O(s)$
- B.  $2Li(s) + \frac{1}{2}O_2(g) \rightarrow Li_2O(s)$
- C.  $Li(s) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}Li_2O(s)$
- D.  $Li(g) + \frac{1}{4}O_2(g) \rightarrow \frac{1}{2}Li_2O(g)$

16. Which statement describes an endothermic reaction?

- A. The bonds broken are stronger than the bonds formed.
- B. The enthalpy of the reactants is higher than the enthalpy of the products.
- C. The temperature of the surroundings increases.
- D. The products are more stable than the reactants.



17. Which instrument would best monitor the rate of this reaction?



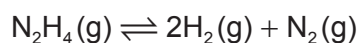
- A. Balance
- B. Colorimeter
- C. Volumetric flask
- D. Gas syringe

18. Which combination has the greatest rate of reaction at room temperature?

|    | Zinc             | CuSO <sub>4</sub> (aq)   |
|----|------------------|--|
| A. | 1.00 g Zn powder | 50.0 cm <sup>3</sup> of 0.200 mol dm <sup>-3</sup> CuSO <sub>4</sub> (aq)  |
| B. | 1.00 g Zn powder | 100.0 cm <sup>3</sup> of 0.100 mol dm <sup>-3</sup> CuSO <sub>4</sub> (aq) |
| C. | 1.00 g Zn strip  | 50.0 cm <sup>3</sup> of 0.200 mol dm <sup>-3</sup> CuSO <sub>4</sub> (aq)  |
| D. | 1.00 g Zn strip  | 100.0 cm <sup>3</sup> of 0.100 mol dm <sup>-3</sup> CuSO <sub>4</sub> (aq) |

19. The equilibrium  $2\text{H}_2(\text{g}) + \text{N}_2(\text{g}) \rightleftharpoons \text{N}_2\text{H}_4(\text{g})$  has an equilibrium constant,  $K$ , at 150°C.

What is the equilibrium constant at 150°C, for the reverse reaction?



- A.  $K$
- B.  $K^{-1}$
- C.  $-K$
- D.  $2K$

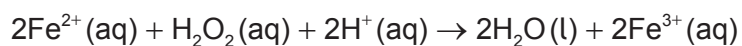
20. Which ions are present in an aqueous solution of Na<sub>2</sub>CO<sub>3</sub>?

- I. HCO<sub>3</sub><sup>-</sup>
  - II. OH<sup>-</sup>
  - III. CO<sub>3</sub><sup>2-</sup>
- A. I and II only
  - B. I and III only
  - C. II and III only
  - D. I, II and III

21. What is the conjugate acid of  $\text{HS}^-$ ?

- A.  $\text{H}_2\text{S}$
- B.  $\text{S}^{2-}$
- C.  $\text{H}_2\text{SO}_3$
- D.  $\text{H}_2\text{SO}_4$

22. What is the change in the oxidation state of oxygen?

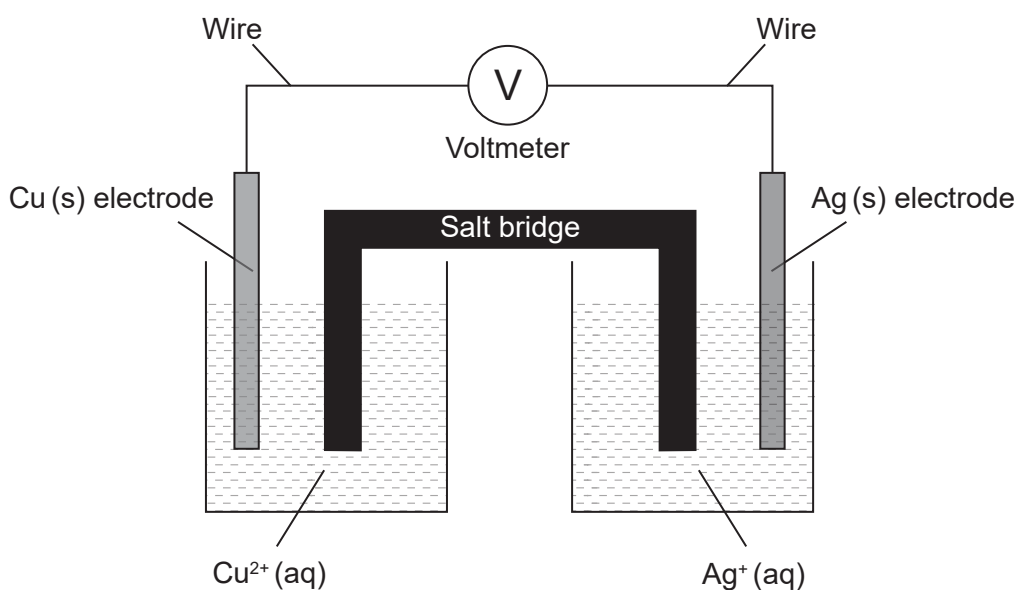


- A. +1
- B. 0
- C. -1
- D. -2

23. Which statement is correct about the electrolysis of molten lead(II) bromide,  $\text{PbBr}_2$ ?

- A.  $\text{Br}^-$  ions accept electrons at the cathode (negative electrode).
- B.  $\text{Pb}^{2+}$  ions accept electrons at the anode (positive electrode).
- C.  $\text{Br}^-$  ions lose electrons at the anode (positive electrode).
- D.  $\text{Pb}^{2+}$  ions lose electrons at the cathode (negative electrode).

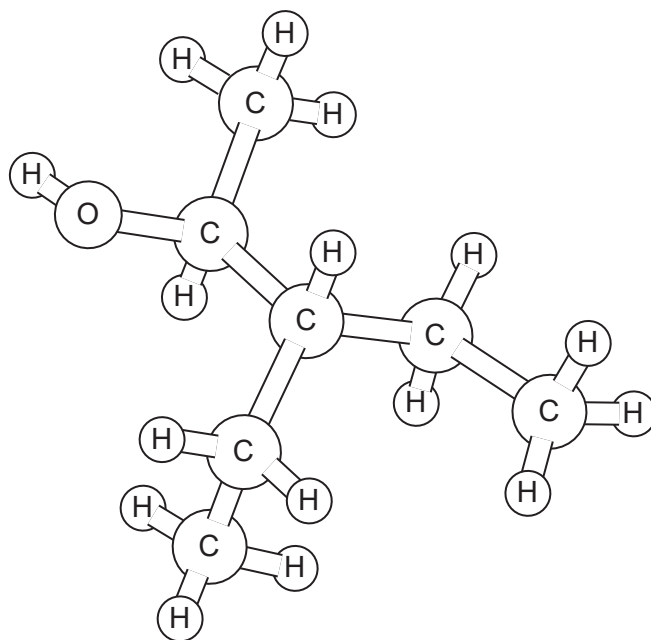
24. Consider this voltaic cell, where Cu is a more reactive metal than Ag:



Which combination describes the movement of charge in this cell?

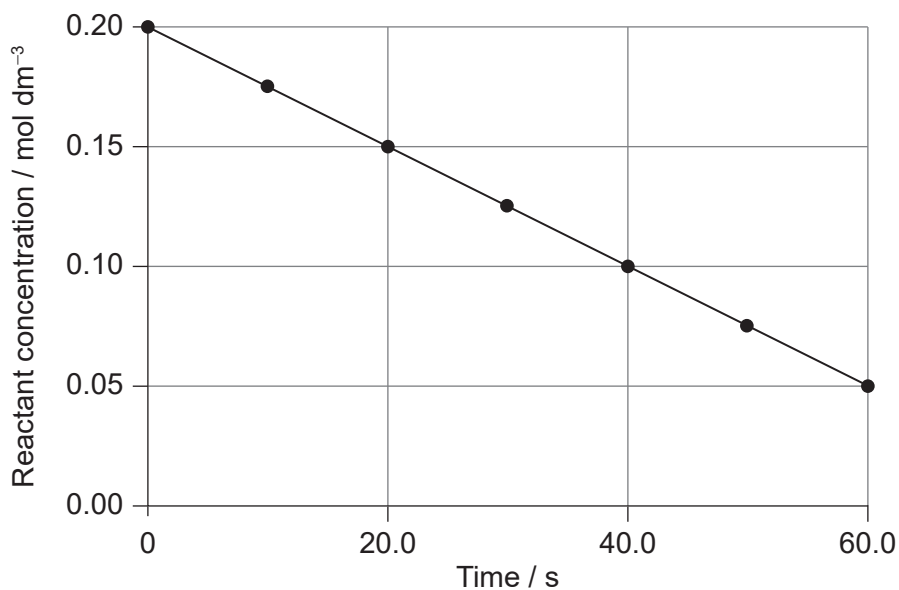
|    | <b>Flow of electrons in wire</b> | <b>Flow of negative ions in salt bridge</b> |
|----|----------------------------------|---|
| A. | Ag(s) to Cu(s)                   | Toward Ag <sup>+</sup> (aq)                 |
| B. | Cu(s) to Ag(s)                   | Toward Ag <sup>+</sup> (aq)                 |
| C. | Ag(s) to Cu(s)                   | Toward Cu <sup>2+</sup> (aq)                |
| D. | Cu(s) to Ag(s)                   | Toward Cu <sup>2+</sup> (aq)                |

25. What is the name of this substance using IUPAC rules?



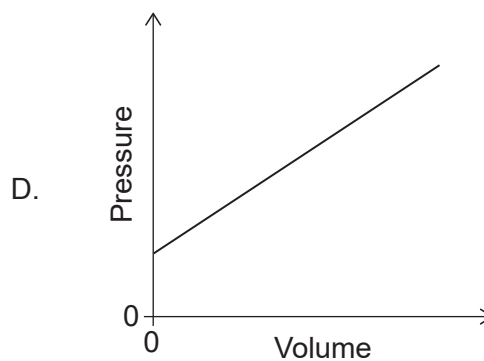
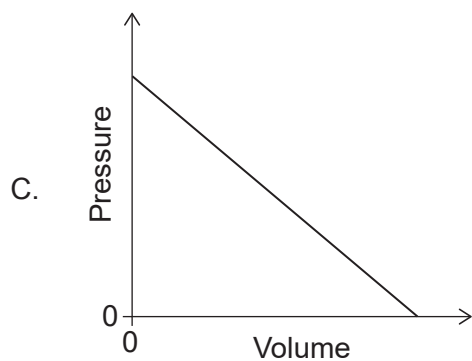
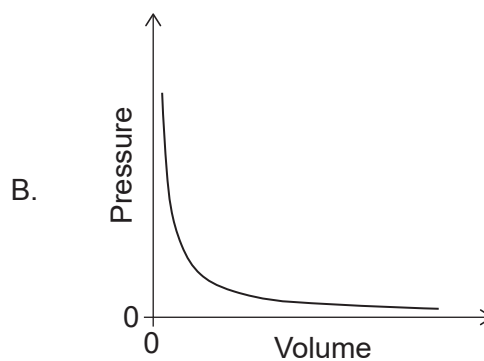
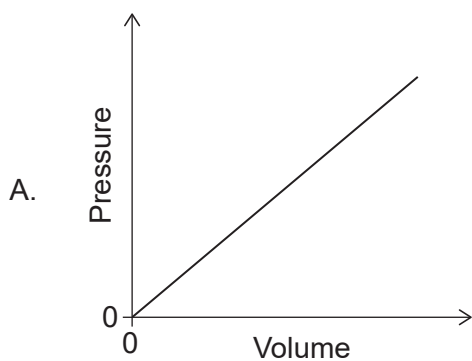
- A. 2-ethyl-1-methylbutan-1-ol
  - B. 1-methyl-2-ethylbutan-1-ol
  - C. 3-ethylpentan-2-ol
  - D. 3-ethylpentan-4-ol
26. Which pair of compounds are structural isomers?
- A. Propane and propene
  - B. Propanal and propanone
  - C. Propan-1-ol and propanal
  - D. Propyl propanoate and propanoic acid
27. What is the general formula of alkynes?
- A.  $C_nH_{2n+2}$
  - B.  $C_nH_{2n}$
  - C.  $C_nH_{2n-2}$
  - D.  $C_nH_n$

28. What is the slope of the graph?

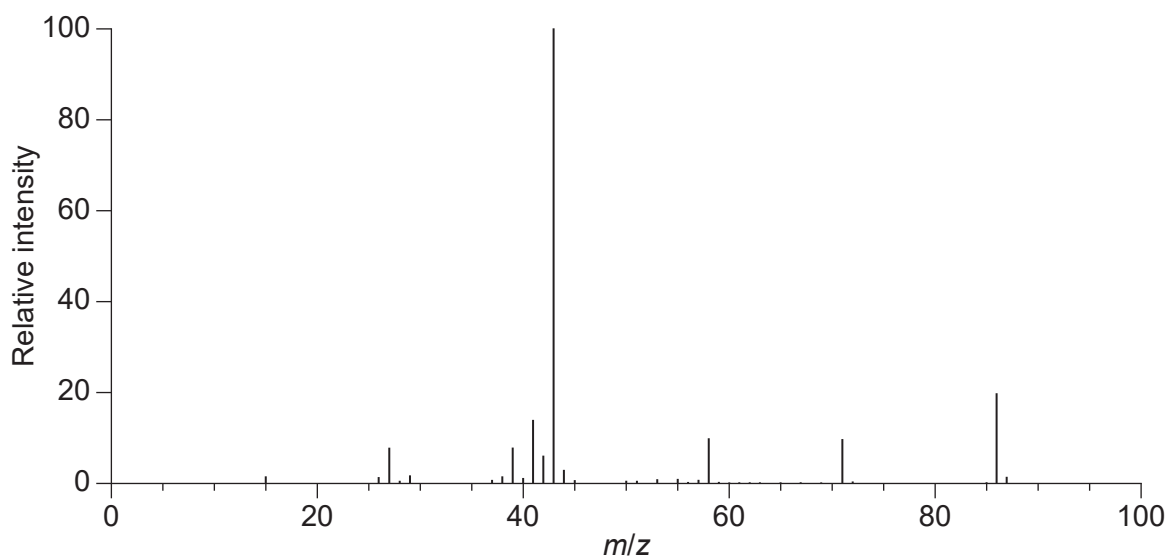


- A.  $-0.0025 \text{ mol dm}^{-3} \text{ s}^{-1}$
- B.  $-0.0025 \text{ mol dm}^{-3} \text{ s}$
- C.  $-0.0033 \text{ mol dm}^{-3} \text{ s}^{-1}$
- D.  $-0.0033 \text{ mol dm}^{-3} \text{ s}$

29. Which graph shows the relationship between the pressure and volume of a sample of gas at constant temperature?



30. What can be deduced from the mass spectrum of  $\text{CH}_3\text{COCH}_2\text{CH}_2\text{CH}_3$ ?



- A. The molar mass is  $43 \text{ g mol}^{-1}$ .
  - B. The atoms have many isotopes.
  - C. The most likely bond to break is C–C between carbons 2 and 3.
  - D. The signal with the largest mass is due to the oxidation of the ketone in the spectrometer.
-

#### References:

14. Chemistry: Atoms First 2e, <https://openstax.org/books/chemistry-atoms-first-2e/pages/9-4-strengths-of-ionic-and-covalent-bonds> © 1999–2021, Rice University. Except where otherwise noted, textbooks on this site are licensed under a Creative Commons Attribution 4.0 International License. (CC BY 4.0) <https://creativecommons.org/licenses/by/4.0/>.
30. NIST Mass Spectrometry Data Center Collection © 2021 copyright by the U.S. Secretary of Commerce on behalf of the United States of America. All rights reserved. 2-Pentanone Mass Spectrum, MS Number 291264. [graph] Available at: <https://webbook.nist.gov/cgi/cbook.cgi?ID=C107879&Units=SI&Mask=200#Mass-Spec2-pentanone> [Accessed 4 May 2020]. Source adapted.